Proceeding: Amendment of the Commission's Rules with regard to WRC-2003 Changes

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Before the
FEDERAL COMMUN ICATIONS COMMISSION
Washington, D.C.

Marlene H. Dortch
Secretary
Federal Communications Commission
445 12th St. S.W.
Washington, D.C. 20554

To the Secretary

PETITION FOR RULEMAKING

Respectfully Submitted,

JANSKY-BARMAT TELECOMMUNICATIONS
INC.

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FEBRUARY 24,
2006

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EXECUTIVE SUMMARY

This Petition For Rule Making concerns modification of the Commission's Rules to incorporate certain results of WRC-03. The results of concern which have yet to be incorporated relate to the Fixed Satellite Service (Earth-to-space) band, 13.75-14.00 GHz. The 2003 ITU-R World Radio Conference modified the conditions for use of this allocation to allow for the implementation of Fixed Service Satellite earth stations as small as 1.2 m whereas today only 4.5 m earth stations are generally permitted under the rules.
Grant of this Petition would greatly enhance the services which would be made possible to the American marketplace, which has been inhibited by the imbalance between the spectrum availability of only 500 MHz in the Ku uplink allocations, compared to the 750 MHz of downlink Ku spectrum. Such services are capable of being provided by a number of geostationary communication satellites already providing service to the United States.

The Petition sets forth the background for this Petition and specifies the nature of the proposed changes.

1. Introduction

This Petition for Rulemaking concerns the modification of the Commission's Rules to reflect certain unimplemented results of the 2003 World Administrative Radiocommunication Conference (WRC-03), and subsequent related action by Study Group 4 of the Radiocommunication Sector of the International Telecommunications Union (ITU) regarding use of the band 13.75-14.00 GHz by the Fixed Satellite Service (FSS). The proposed rule changes will allow for the further development and use of the Fixed Satellite Service in the United States through balancing the amount of spectrum available for Ku-band FSS uplink transmissions with spectrum for FSS downlink Ku-band transmissions through expansion of available spectrum particularly for small earth stations with antenna sizes as small as 1.2m.

This imbalance in uplink FSS spectrum in relation to downlink spectrum has been in existence for over 20 years, and has inhibited the development of Ku band V-Sat type networks and their associated markets.

This Petition provides information on the background of the 13.75-14.00 GHz allocation, a discussion of the existing FCC rules and what should be changed, a statement concerning the public benefit, and associated appendices.

II. Background

A. Pre-WRC-03 Use of the band 13.75-14.00 GHz

The history of the band 13.75-14.00 GHz use of the Fixed Satellite Service (FSS) begins at WARC-92 held in Torremolinos, Spain. This conference contained an agenda item which provided for the expansion of Ku-band uplink spectrum to bring it into balance with the then available downlink spectrum allocations for the FSS at Ku band. Before WARC-92 there was 750 megahertz available for downlink Ku band spectrum and 500 megahertz available for uplink. Thus there was an imbalance of 250 MHz for the uplink.

As it was important that the additional spectrum be contiguous to the existing uplink spectrum, an initial proposal was made by the satellite community to establish an FSS primary allocation in the band 14.50-14.75 GHz. However, this was met with considerable opposition from a number of countries including the United States. Subsequently, a proposal was made to allocate the band 13.75-14.00 GHz to the FSS. However, as this proposal was made at the conference itself without adequate preparatory analysis, no sharing studies had been performed in advance to establish a viable basis for coexistence of the FSS with other services in the band with equal Primary status in particular the Radiolocation Service (Radars) (RLS).

The WARC-92 added the FSS to the band 13.75-14.00 GHz on a Primary basis giving it co equal status with the Radiolocation Service (RLS). However, it also adopted footnotes to this allocation applicable to the FSS which provided the basis for protecting the RLS. The applicable footnotes were Nos. 5. 502, and 5. 503. No. 5.502 limited the minimum size antenna diameter of the FSS transmitting earth station to 4.5 m and the e.i.r.p of any emission to a minimum of 68 dBW. These footnotes and other related footnotes were adopted by the US and are effectively the basis for the existing FCC rules for the FSS in this band.

At WRC-2000, Istanbul, several countries proposed to reduce the minimum size earth station in this band to 1.2 m. Indeed, it was learned that some countries were actually implementing the use of earth stations with this size antenna contrary to the existing rules. It was only with great effort that such a step was delayed due to lack of study of the sharing conditions which would apply, but a resolution was agreed to put the matter on the agenda of WRC-03. Subsequently, the next three years were devoted to developing the sharing criteria which would permit the use of FSS Earth stations in the band as small as 1.2 m.

B. Results of WRC-03

WRC-03 had on its agenda consideration of changing the footnotes referenced above to permit the use of earth stations with smaller diameter antenna. The lead group within the ITU-R for addressing this agenda item was a special Task Group, TG-4-7-8. This was in recognition of the co-primary services in the band: Fixed Satellite Service, Radiolocation Service, and the Space Research Service.

The technical and regulatory preparation for the agenda item was carried out in this group. The material developed analyzed the sharing situation particularly between the FSS and the RLS as reflected in the Conference Preparatory Report (CPM).
It was indicated that the FSS earth stations could use smaller antenna sizes in the 13.75-14.00 GHz even as small as 1.2m. The principle difficulty concerned those earth stations of such a size which could be located near the coast of a country. Considerable effort was devoted to developing a methodology which would provide a basis for appropriately locating small earth stations sufficiently distant from a coast to avoid unacceptable interference to the Radiolocation Service when used on ships. The principle RLS application in this band is ship borne radars.

In consequence of the analyses and methodologies developed in TG 4-7-8, and reflected in the CPM, the WRC-03 revised footnotes Nos. 5.502, and 5.503 to reflect this new sharing situation. The new footnotes state:

5.502 "In the band 13.75-14.00 GHZ, an earth station of a geostationary fixed-satellite service network shall have a minimum antenna diameter of 1.2m and an earth station of a non-geostationary fixed-satellite service system shall have a minimum antenna diameter of 4.5 m. In addition, the e.i.r.p., averaged over one second, radiated by a station in the radiolocation or radionavigation services shall not exceed 59 dBW for elevation angles above 2 degrees and 65 dBW at lower angles. Before an administration brings into use an earth station in a geostationary-satellite network in the fixed satellite service in this band with an antenna size smaller than 4.5 m, it shall ensure that the power flux- density produced by this earth station does not exceed:

-115 dB (W/ (m2. 10 MHz)) for more than 1% of the time produced at the low water mark, as officially recognized by the coastal
State.

-115 dB (W/ (m2. 10 MHz)) for more than 1 % of the time
produced
3m above ground at the border of the territory of an
administration
deploying or planning to deploy land mobile radars in this band, unless prior agreement has been obtained.

For earth stations within the fixed-satellite service having an antenna
diameter
greater than or equal to 4.5m, the e.i.r.p of any emissions should be at least
68
dBW and should not exceed 85 dBW. (WRC-03).

5.503 In the band 13.75-14.00 GHz, geostationary space stations in the space research service for which information for advanced publication has been received by the Bureau prior to 31 January 1992 shall operate on a secondary basis. Until those space stations in the space research service for which information for advanced publication has been received by the Bureau prior to January 1992 cease to operate in the band:

- in the band 13.77-13.78 GHz, the e.i.r.p density of emissions from any earth station in the fixed satellite service operating with a space station in geostationary orbit shall not exceed:

i) 4.7D+28 dB(W/40 kHz), where D is the fixed satellite earth station antenna diameter(m) for antenna diameters equal to or greater than 1.2 m And less than 4.5 m.

ii) 49.2 + 20 log(D/4.5)dB(W/40 kHz), where D is the fixed satellite service earth station diameter(m) for antenna diameters equal to or greater than 4.5 m and less than 31.9 m.

iii) 66.2 dB(W/40/ kHz) for any fixed satellite service earth station antenna diameter(s) greater than 39.1m

iv) 56.2 dB(W/40/kHz) for narrow band (less than 40 kHz of necessary bandwidth) fixed satellite earth station emissions from any fixed satellite earth station having an antenna of 4.5 m or greater;

- the e.i.r.p. density of emissions from any earth station in the fixed satellite service operating with a space station in non-geostationary satellite orbit shall no exceed 51 dBW in the 6 MHz band from 13.772 to 13.778 GHz.

Automatic power control may be used to increase the e.i.r.p. density in these frequency ranges to compensate for rain attenuation, to the extent that the power flux-density at the fixed satellite service space station does exceed the value resulting from use by an earth station of an e.i.r.p. meeting the above limits in clear sky conditions.(WRC-03)."

The United States recognizes this modification to the international Radio Regulations as a signer of The Final Acts of WRC-03, and in accordance with the provisions of these Acts, their provisions became international law as of July 1, 2003 (See special dates in Article 59 of the Radio Regulations).

C. Development of ITU-R Recommendation

WRC-03 also adopted Resolution 144 which invited the ITU-R to develop Recommendations to establish technical or operational methods to facilitate sharing and greater flexibility in the deployment of FSS earth stations smaller than 4.5 m in the band 13.75-14.00 GHz, and which also could be used for establishing bi-lateral agreements between administrations. Such an effort was successfully undertaken by ITU-R Working Party 4A, Efficient Use of the Geostationary Orbit.

ITU-R WP-4A developed a Recommendation which contains three methods for determining whether FSS earth stations at a given location can transmit in the band 13.75-14.00 GHz without exceeding the pfd specified in RR 5.502(WRC-03). The Recommendation also provides additional measures that administrations of small and narrow countries can consider when deploying FSS earth stations. This Recommendation was agreed by WP-4A's parent Study Group 4, and subsequently also approved by ITU Administrations, and as a result is an internationally recognized standard. The Recommendation has already been used as the basis to implement small FSS earth stations in the band 13.75-14.00 GHz in other countries.

The referenced Recommendation is ITU-R Recommendation S. 1712," Methodologies for Determining whether an FSS earth station at a given location could transmit in the band 13.75-14.00 GHz without exceeding the pfd limits in RR 5.502, and Guidelines to Mitigate excesses.". A copy of this agreed recommendation which is useful in deploying earth stations as small as 1.2m may be found at Appendix A., and would be useful in a modification of the Commission's rules with respect to implementing the results of WRC-03 in the band 13.75-14.00 GHz.

III. Discussion

A. Existing FCC Regulations

The existing FCC Regulations for the band 13.75-14.00 GHz are basically those which were adopted at WARC-92. The US Table of Allocations for this band is found in Part 2.106 of the FCC rules, and are reflected in Table 1.0 below:

Table 1.0
Present U.S Allocations for the band 13.75-14.00 GHz

International Table	Federal Government	Non-Fed Government	FCC Rules
13.75-14.00 GHz FIXED-SATELLITE (Earth-space) 5.484A RADIOLOCATION Standard Frequency and time signal satellite (Earth-to-space Space Research 4.99,5.500,5.502,5.503,5.503A	13.75-14.00 GHz RADIOLOCATION G59 Standard Frequency and time signal satellite (Earth-to-space) Space Research US 337 5.503A,US356,US357	13.75-14.00 GHz FIXED SATELLITE (Earth-to-space) US337 Radiolocation Standard Frequency and time signal satellite (Earth-to-space) Space Research 5.503A,US356,US357	Satellite Communications(25) Private Land Mobile (90)

Except for separating the regulatory responsibilities between NTIA (Federal Government) and the FCC (Non Fed. Government) the domestic US allocation table is the same as the International table after WRC-2000. It has not been changed to reflect the results of WRC-03. Further, the associated Part 25 rules do not reflect the development , adoption , and utilization of the ITU-R Recommendation S. 1712 in response to Resolution 144 (WRC-03) to provide for implementation of earth stations as small as 1.2 m in the band 13.75-14.00 GHz.

Nos. US 356, and 357 have essentially incorporated the substance of Nos. 5.502, and 5.503 from WARC-92 into the US domestic Table. These are the basic rules as they apply today. In addition as the allocation has shared jurisdiction between the

NTIA and the FCC any new earth station with an antenna less than 4.5 m requires coordination with the NTIA.

The existing Part 25 rules make little mention of the use of the FSS in the band 13.75-14.00 GHz. However, a few earth stations have received authorization to use the band. These are
those earth stations which conform to the conditions associated with the US footnotes found in the existing rules e.g. having antennas of 4.5 meters or larger. It appears that to date no earth stations which have antennas less than 4.5 meters, have been granted a waiver of these existing rules by demonstrating through application of the method in Recommendation S. 1712 that the Radiolocation Service is protected. The number of earth stations receiving authorization to use this band has been very small, yet there are a number of in orbit FSS networks which have the capability to provide service in this band, and are inhibited due to lack of rules to facilitate their implementation.

B. Requested Amendment to Parts 2.106 and 25, Sec. C of the FCC

This Petition requests that the FCC modify its rules found in Parts 2 and 25 to implement the results of WRC-03 and the associated Resolution 144 in the band 13.75-14.00 GHz. It is more than two and one half years since the relevant results of WRC-03 have come into force. In addition the ITU-R with active US participation and agreement have adopted a Recommendation which contains the necessary methods which when applied will ensure the protection of the Radiolocation Service.

To bring about the implementation of the results of WRC-03 for the band 13.75-14.00 GHz, the following rule changes are requested:

1.0 In Part 2.106 conform Nos. US 356 and US 357 to the language found in Nos. 5.502 (WRC-03), and 5.503 (WRC-03). This will establish the basic sharing conditions between the FSS and the RL which were adopted at WRC-03 to permit earth stations in the band with antennas as small as 1.2 meters in the FSS provided they can demonstrate protection of the Radiolocation Service in the band.

2.0 In Part 2.106 consider the suppression of No. 5.503A as this note was suppressed by WRC-03.

3.0 In Part 25.204(f) text needs to be added to provided power limits in the band 13.75-14.00 GHz when the antenna is between 1.2 m and 4.5 m.

4.0 Under Part 25.115, Application for earth station authorization, it is requested that the FCC rules be modified to add a new paragraph which states that earth station applications in the band 13.75-14.00 GHz which propose to have

antennas less than 4.5 meters , need in addition to the other requirements specified, use a mechanism based Recommendation S. 1712 as a basis for the blanket licensing of such earth stations that meet the conditions for protection of the Radiolocation Service in the band. The mechanism for determining if the conditions are met could be a nomagraph indicating permitted distance from the coast as a function of earth station antenna size and e.i.r.p.
This mechanism, once agreed with NTIA would obviate the need for coordinating individual earth stations in the band with antennas ranging in size between 1.2 m and 4.5 m.

5.0 Also, under Part 25.115 it is requested that provision be made to permit the routine authorization of earth stations which have antennas equal to or greater than 4.5 meters without the need to carry out the calculations indicated above. There is no provision for such authority now.

6.0 Under Part 25.134 it is requested that a new section be added to provided to accommodate V-Sat operations having earth stations with antennas as small as 1.2 m

Appropriate language for these requested changes to the referenced FCC rules may be found in Appendix B.

C. The Public Interest Would Be Served by Grant of this Petition

As noted in the Background, the impetus for creating and FSS allocation in the 13.75-14.00 GHZ band at the WRC 1992 was the imbalance between the downlink and uplink FSS allocations available for commercial use in the Ku band part of the spectrum which could be utilized for the delivery of services via communication satellite in the geostationary orbit to all parts of the United States. In practice this expectation has yet to be fulfilled. As a consequence of the constraints imposed in the band, it has not been possible to develop and deploy FSS terminals with antennas as small as 1.2 meters in the band. There is considerable demand for such stations, and the limit on accommodating them in the 14.0-14.5 GHz band is rapidly approaching. As the other five hundred megahertz of Ku band FSS spectrum in the companion bands 14.00-14.25 GHz, and 14.25-14.500 GHz is heavily developed, this has resulted in a denial of service. There are many locations in the United States where such terminals can be used to deliver a variety of services. The adoption of rules such as those requested would permit the needed and long overdue expansion of such services.

In addition, there are existing FSS satellites which have the capability to provide such services through on board transponders now serving the United States. Significant enhancement of service would result from the modification of the FCC rules suggested above.

In summary, the Public Interest would be served by adopting the requested changes to the FCC rules. Such modifications would permit the implementation of FSS terminals having antennas as small as 1.2 meters in the band 13.75.14.00 GHz.

IV. Conclusion

This Petition requests the Commission to modify its rules to implement the results of WRC-03 in the band 13.75-14.00 GHz. Grant of this Petition will provide the technical and regulatory basis for addressing the imbalance in FSS Ku band spectrum available to FSS operators to provide services utilizing terminals with antennas as small as 1.2m. The proposed rule changes requested can obtain this objective while at the same time protecting the users of the Radiolocation Service which operate in the same allocation. Making the proposed changes would greatly enhanced the possible services available through Ku band type applications throughout the United States.

The Commission is urgently requested to grant this Petition.

APPENDIX A

RECOMMENDATION ITU-R S.1712

Methodologies for determining whether an FSS earth station at a given location could transmit in the band 13.75-14 GHz without exceeding the pfd limits in No. 5.502 of the Radio Regulations, and guidelines to mitigate excesses

RECOMMENDATION ITU-R S.1712

Methodologies for determining whether an FSS earth station at a given location could transmit in the band 13.75-14 GHz without exceeding the pfd limits in No. 5.502 of the Radio Regulations, and guidelines to mitigate excesses

(2005)

Scope

WRC-03 adopted Resolution 144 to invite the ITU-R to develop Recommendations to establish technical or operational methods to facilitate sharing and greater flexibility in deployment of FSS earth stations smaller than 4.5 m in the band 13.75-14 GHz in conformity with Radio Regulations (RR) No. 5.502, and which may also be used to establish a basis for bilateral agreements between administrations.

This Recommendation proposes three methods for determining whether FSS earth stations at a given location can transmit in the band 13.75-14 GHz without exceeding the pfd limit in RR No. 5.502. It also provides additional measures that administrations of small and narrow countries can consider when deploying FSS earth stations.

The ITU Radiocommunication Assembly,

considering

a) that WRC-03 revised the sharing constraints on the fixed-satellite service (FSS) (Earth-to-space) in the band 13.75-14 GHz;

b) that this FSS band is shared with the radiolocation and radionavigation services;

c) that the revised sharing conditions approved at WRC-03 permit the operation of geostationary FSS earth stations in the band 13.75-14 GHz with antennas of diameter D, with 1.2 m $\leq D <$ 4.5 m;

d) that No. 5.502 of the Radio Regulations (RR) requires an administration planning to operate, within its country, an FSS earth station having an antenna of diameter D less than 4.5 m, and transmitting to a GSO satellite in the band 13.75-14 GHz, to ensure that the pfd that this earth station produces anywhere on the border of a neighbouring country at a height of 3 m above ground, and/or anywhere on its sea border (if it has one) at a height of 36 m above the low-water mark, does not exceed −115 dB(W/(m^2 · 10 MHz)) for more than 1% of the time;

e) that, since propagation loss increases with distance, and on overland paths is strongly influenced by the nature of the terrain, earth stations located sufficiently far from the neighbouring country's border or from a low-water mark may meet the pfd limit without the application of interference mitigation techniques (e.g. local shielding), and therefore methods to identify the areas in a country where this is so would assist administrations to comply with the requirement in *considering* d);

f) that natural or man-made site shielding could attenuate the signal transmitted by an earth station in the direction of a neighbouring country's land border and/or low-water mark;

g) that the use of specific types of earth stations with improved side-lobe performance could reduce the signal produced by an FSS earth station at the neighbouring country's land border and/or low-water mark;

h) that it is appropriate to employ the relevant information in ITU-R Recommendations as a basis for the methods mentioned in *considering* e), and that it may be appropriate to use a terrain database covering any country in which it is planned to operate FSS earth stations with antenna diameter D less than 4.5 m in the 13.75-14 GHz band;

j) that Resolution 144 (WRC-03) resolves that the administrations of geographically small or narrow countries may exceed the limitations on FSS earth station power flux-density at the low-water mark in RR No. 5.502 if such operation is in conformance with bilateral agreements with administrations deploying maritime radiolocation systems in the band 13.75-14 GHz;

k) that Resolution 144 (WRC-03) further resolves that the technical or operational methods which will further facilitate sharing may allow greater flexibility in the deployment of FSS earth stations in the band 13.75-14 GHz, in conformity with RR No. 5.502, and which may also be used as a basis for the establishment of such bilateral agreements between administrations,

noting

a) that RR No. 5.503 places additional constraints on the operation of FSS earth stations in the 10 MHz band from 13.77 to 13.78 GHz,

recommends

1 that the method in either Annex 1 or Annex 2 or Annex 3, or in a combination of these annexes, as deemed appropriate by the concerned administrations, including those countries referred to in *considering* j), should be used for determining whether an earth station proposed to operate in the 13.75-14 GHz band would meet the pfd limits of RR No. 5.502;

2 that, in addition, in the case of small or narrow countries, the information in Annex 4 of this Recommendation should be used to help in meeting the pfd limits of RR No. 5.502, and/or as a basis for the establishment of bilateral agreements between administrations when seeking agreement for relief of the pfd limits of RR No. 5.502.

Annex 1

Method 1: Minimum separation distance curves based on Recommendation ITU-R P.452, utilizing FSS earth station height and e.i.r.p. density toward the horizon, latitude, and possibly terrain heights[1]

This method produces two curves, using a smooth Earth model, showing the minimum separation distance from the low-water mark or neighbouring country's land border, an FSS earth station would need to meet in order to respect the pfd limits in RR No. 5.502, as a function of the earth station e.i.r.p. density toward the horizon. The primary curve gives the line-of-sight (LoS) separation distance. The secondary curve gives the trans-horizon separation distance. An FSS earth station deployed at a distance greater than or equal to the minimum separation distance is assumed to meet the pfd limit criteria. Besides determination of whether the path to the low-water mark or border is LoS or trans-horizon, no further analyses are required. Note that deployment in areas excluded by this method is still possible provided a potential site can be shown to meet the pfd limit criteria through application of either Method 2 or 3 (Annexes 2 and 3). In order to fully account for the variability of terrain in the real world, this Method is separated into three steps of increasing complexity. Step A is by far the simplest and does not account for terrain. In fact, this step assumes a *flat* Earth where all paths are LoS. Step B assumes a spherical Earth with a nominal radio horizon but does not consider the effect of intervening terrain. Like Step B, Step C assumes a spherical Earth, but unlike Step B it does take into consideration the effect of intervening terrain. Each step in order will increase the size of the potential FSS deployment area (exposing the largest possible area using Step C). It is given that if Step A or B shows that a potential deployment site meets the pfd limit criteria, then the following step(s) need not be performed. At the discretion of the user, Steps B or C may be employed without previously implementing Step A.

In order to calculate the value of the distance, some basic assumptions and propagation models are required. Radiocommunication Study Group 3 has developed many propagation models for this specific purpose, and Recommendation ITU-R P.452-11 has been used in many similar sharing situations and would appear to be the most appropriate for the propagation situation covered by Recommendation ITU-R P.452-11.

An in-depth description of Method 1 follows.

Step A: All paths are assumed to be LoS. The LoS curve in Fig. 4 is used to determine the minimum separation distance as a function of earth station e.i.r.p./10 MHz radiated by the station towards the low-water mark (or border). Note that the curve is derived from the LoS loss from Recommendation ITU-R P.452-11 ($p = 1.0\%$). Since this is a flat Earth model, the curve is independent of factors such as local ΔN and antenna height above terrain. If the potential deployment site is farther from the low-water

[1] Method 2 will maximize the area in which deployments may be made without requiring individual site analysis. If digital terrain data for a country is not available, or a simpler approach is desired, then Method 1 will permit contours to be developed that are somewhat more conservative than the digital terrain approach of Method 2.

mark (or border) than the required separation distance from the LoS curve, then the station is assumed to comply with the pfd limit criteria of RR No. 5.502. If the path length is smaller than the required separation distance, then proceed to Step B.

Step B: This step assumes a spherical Earth and thus requires the determination of a nominal radio horizon. First, find the effective Earth radius, a_e, using the local ΔN and equations (5) and (6) of Recommendation ITU-R P.452-11 (convert to metres). The radio horizon can then be calculated from the following equation:

$$RHorizon_{nominal} = \sqrt{2 \cdot a_e} \cdot \left(\sqrt{h_0} + \sqrt{h_{es}}\right)/1\,000 \qquad \text{km}$$

where:

h_0 = 36 m for a low-water mark path or 3 m for a land border path

h_{es}: earth station height (m) above mean sea level.

If the earth station site is within the nominal radio horizon of the low-water mark (or land border), then the required separation distance is found using the LoS curve of Fig. 4. If the earth station site is beyond the nominal radio horizon, then determine the required separation distance using the trans-horizon curve of Fig. 4. If the potential deployment site is farther from the low-water mark (or border) than the required separation distance from the applicable curve, then the station is assumed to comply with the pfd limit criteria of RR No. 5.502. If the path length is smaller than the required separation distance, then proceed to Step C.

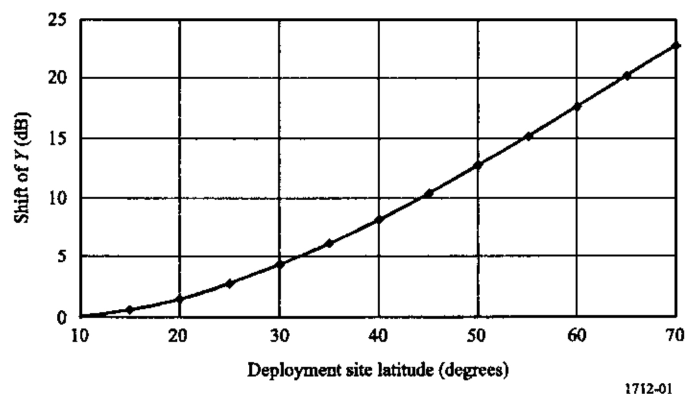
Step C: This step also assumes a spherical Earth. Furthermore, it requires a more detailed analysis of the paths toward the low-water mark (or border). Appendix 2 to Annex 1 of Recommendation ITU-R P.452-11 is used to determine if a path is LoS or trans-horizon. The specific procedure is detailed in § 4.1 of that appendix: "Test for a trans-horizon path". The terrain data can be taken from Digital Elevation Maps or even derived from the elevation contours of printed maps. Since in actual terrain, the path with the lowest loss is not necessarily the shortest path, several paths in radial around the potential earth station site should be tested. If any path is shown to be LoS, then the required separation distance is found using the LoS curve of Fig. 4 (using the shortest LoS path). If the test shows that all paths are trans-horizon, then the required separation distance is found using the trans-horizon curve of Fig. 4. If the potential deployment site is farther from low-water mark or the neighbouring country's land border than the required separation distance from the applicable curve, then the station is assumed to comply with the pfd limit criteria of RR No. 5.502. If the path length is smaller than the required separation distance, it is likely non-compliant with the pfd limit.

It is important to note that the required separation distance found with any of the three steps above is not an absolute minimum. If the earth station distance to the low-water mark or the neighbouring country's land border is smaller than the required value, further analysis using either Method 2, which includes digital terrain data and propagation modelling, or Method 3, which also includes terrain data and allows for factors such as site shielding, may be used to verify whether the pfd limit criteria in RR No. 5.502 can be met.

As described above, the use of Method 1 requires two curves (for different path types) that give the minimum distance X to the low-water mark (or land border), as a function of the e.i.r.p. density toward the horizon, to meet the pfd limit criteria. Deployment sites that are less than X from the low-water mark (or land border) are possible but require application of the other methods. In order to calculate the (LoS) value of X some basic assumptions and propagation models are required. The LoS curve is calculated directly from the LoS equation of Recommendation ITU-R P.452-11. This is equation (9) of § 4.2 of the Recommendation. Use an appropriate frequency and set the percentage of time p to 1.0%. The resulting loss is used with equation (2) to find the e.i.r.p./distance combination that satisfies the pfd limit. The trans-horizon curve is simply the LoS curve shifted up the e.i.r.p. scale by Y dB. The value of Y is found from the curve in Fig. 1. As noted above, the pfd level given in RR No. 5.502 specifies the height at the low-water mark or at the border of a neighbouring country.

FIGURE 1

Trans-horizon curve shift as a function of latitude



Example of application of Method 1

In considering Step A, in some countries typical very small aperture terminal (VSAT) earth stations operating in the 13.75-14.5 GHz band are limited in the input power density level into the antenna to –14 dB(W/4 kHz). For a typical 64 kbit/s quadrature phase shift keying VSAT digital carrier (rate 1/2 forward error correction with Reed Solomon coding) with an approximate bandwidth of 84 kHz, this level would produce an input power density P_d of:

$$P_d = -14 + 10 \log (84/4) = -0.8 \text{ dB(W/84 kHz)}$$

Assuming that the off-axis angle to the low-water mark in elevation and azimuth exceeds 48° then the gain of the antenna would be –10 dBi and the transmit e.i.r.p. density, assuming one carrier within the 10 MHz bandwidth, would be:

$$(\text{e.i.r.p.})_d = -10.8 \text{ dB(W/10 MHz) bandwidth}$$

Further assume that the path length from the earth station to the low-water mark (in this example the low-water mark was considered to be co-located with the coastline) is 44 km, local $\Delta N = 40$, and that the earth station height is 20 m above mean sea level (AMSL). The latitude is 35°, which yields a 6 dB shift for the trans-horizon curve. Step 1 begins with comparison of the off-axis e.i.r.p. with the LoS curve of Fig. 4. It follows from the curve that the LoS required separation distance would be approximately 66 km. Since the actual path length is less than required minimum separation distance, Step A fails to show compliance with the pfd limit.

Under Step B, the nominal radio horizon is calculated to be 43.3 km. As the actual path length is greater than the nominal radio horizon, the path must be trans-horizon. Therefore, the minimum separation distance can be found using the trans-horizon curve of Fig. 4. Using that curve, a station with an off-axis e.i.r.p. of –10.8 dBW requires a minimum separation distance of approximately 35 km. In this case, the actual path length is greater than the required minimum separation distance. Therefore, Step B shows that this earth station complies with the pfd limit. If Step B had failed to show compliance, analysis using a more accurate estimation of the true radio horizon would follow under Step C.

In the case of a 512 kbit/s carrier with a 669 kHz bandwidth, the e.i.r.p. density would be:

$$(\text{e.i.r.p.})_d = -14 + 10 \log (669/4) - 10 = -1.8 \text{ dB(W/10 MHz)}$$

Step A shows a required minimum separation distance of approximately 140 km would be required. If Steps B or C can show that the path is trans-horizon, then a minimum separation distance of approximately 83 km would be required.

Example of Method 1, Step C

In considering Step C, a potential earth station site is indicated on the example map in Fig. 2. Steps A and B do not show this site to be in compliance with the pfd limit. Therefore, Step C of Method 1 will be utilized. Contours from the map will be used to estimate the radio horizon on paths between the site and different points along the coast (low-water mark). Assume the following parameters:

Earth station e.i.r.p. toward horizon in all directions = –10.8 dBW

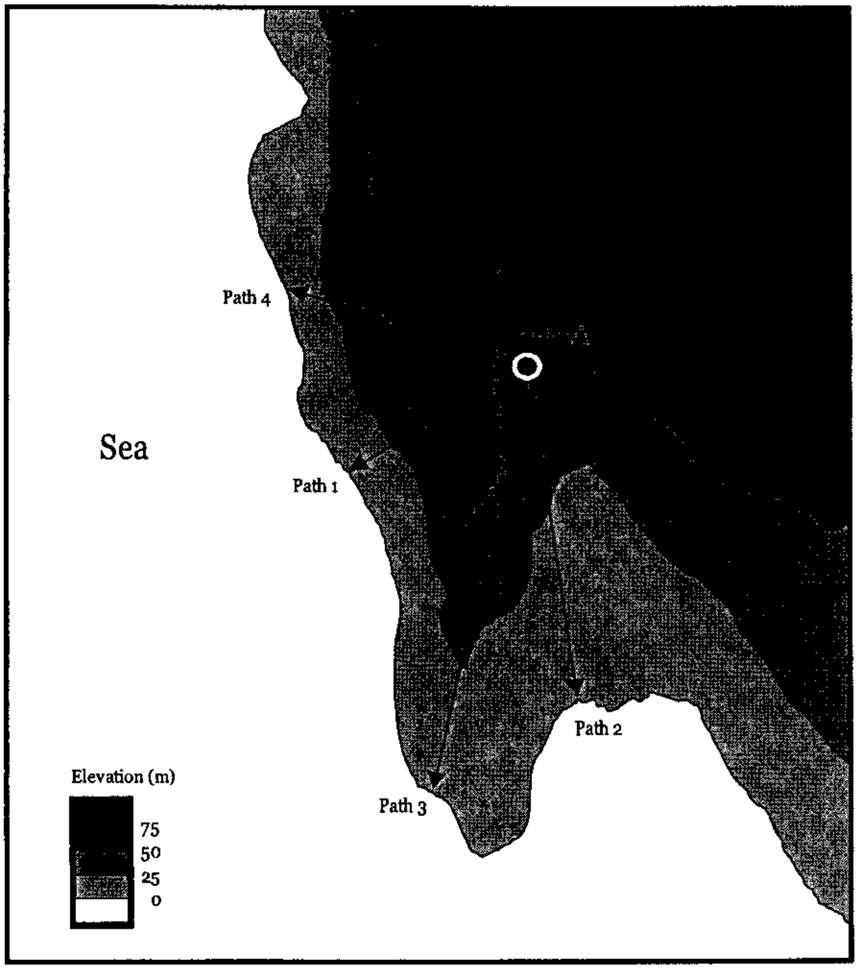
Earth station height AMSL = 40 m

Local annual mean ΔN = 45

Latitude is 35°.

FIGURE 2

Example contour map showing potential ES site



Path lengths:

1 37 km
2 61 km
3 80 km
4 41 km

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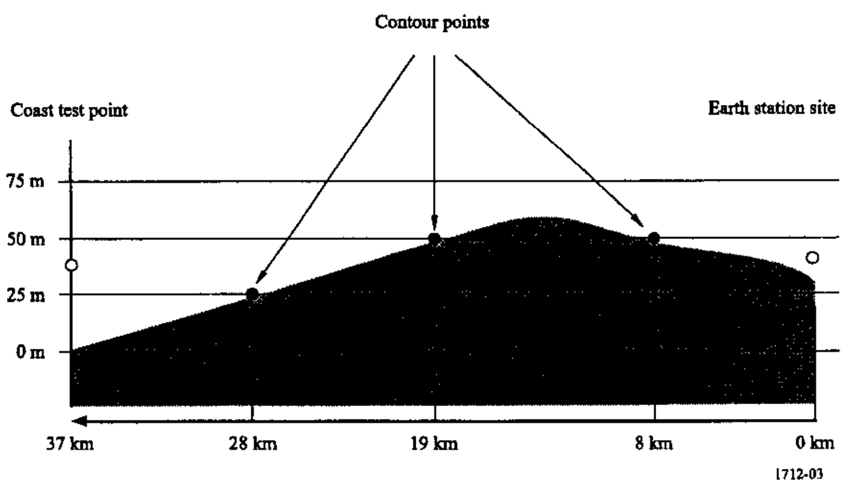
A quick check of Fig. 4 shows that the LoS required separation distance for this earth station (ES) is 63.5 km. The shortest path to the low-water mark (Path 1) is clearly much less than the required LoS distance. Step A does not show compliance. Using ΔN and the earth station height AMSL shows that the nominal radio horizon is 52.1 km. Since the length of Path 1 is less than the nominal horizon the required separation distance remains unchanged. Step B fails.

Step C begins with the trans-horizon test found in Appendix 2 to Annex 1 of Recommendation ITU-R P.452-11. The paths are divided into sections to reflect the different elevations along each part of each path. Evenly spaced increments are recommended but this is not necessary. The Recommendation ITU-R P.452 test checks if the physical horizon elevation angle as seen by the earth station, θ_{ES}, is greater than the angle subtended by the angle from the coastal test point, θ_{TP}. See the Recommendation for full details of the procedure. Making the necessary calculations with Path 1 shows that $\theta_{ES} = 0.8$ mrad and $\theta_{TP} = -2.2$ mrad. Since $\theta_{ES} > \theta_{TP}$, this path is trans-horizon. Note that while Path 2 and Path 3 do not cross contours higher than the earth station, their lengths exceed the nominal radio horizon found in Step B. Therefore, these are known to be trans-horizon without application of the Recommendation ITU-R P.452 test. Path 4 is both longer than Path 1 and crosses a higher contour. Calculation of the angles shows this path is indeed trans-horizon. By inspection, there are no other paths that would be expected to produce results different from the paths shown in the map above. Therefore, this earth station site is not within LoS of any point on the coast (low-water mark). The trans-horizon curve of Fig. 4 shows that the required separation distance for this earth station is 34 km. Since the shortest path is greater than this value, the earth station site is found to be compliant with the pfd limit criteria.

FIGURE 3

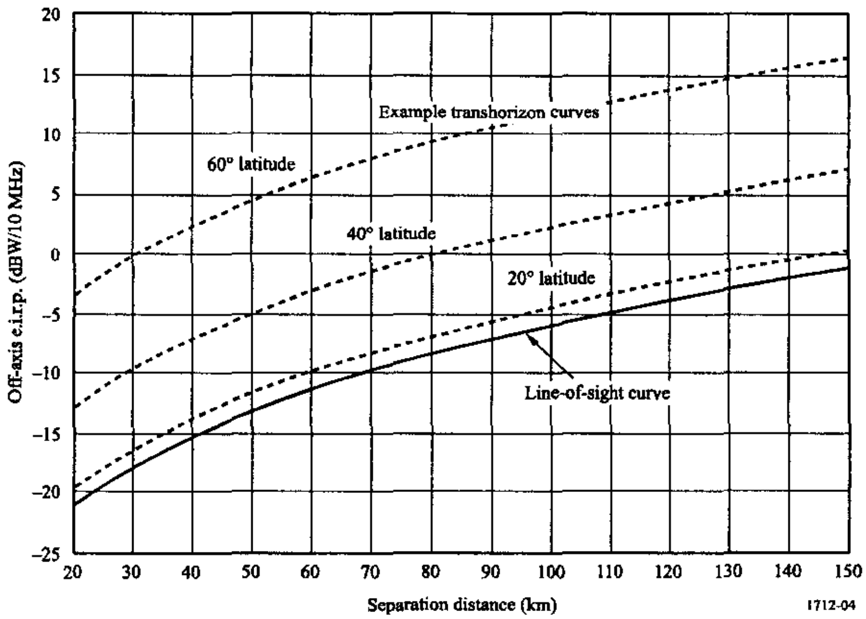
Profile of path 1



Note that the true peak in the profile in Fig. 3 was not actually used in the calculations. The contour map in Fig. 2 only provided with certainty elevation data in 25 m increments. A higher resolution source of terrain data could have been used to take advantage of the true height of the intervening terrain.

FIGURE 4

***Method 1*: Separation distance curves (minimum distance from the low-water mark as a function of the e.i.r.p. density toward the horizon)**



Note that the LoS curve is derived from the loss for LoS paths found in Recommendation ITU-R P.452-11. The trans-horizon curve is simply the LoS curve shifted up the e.i.r.p. axis by *Y* dB. In reality, diffraction loss is not simply the LoS loss shifted by a constant value. Further analysis of the Recommendation ITU-R P.452-11 model may show that the trans-horizon curve may require some adjustment.

Annex 2

Method 2: pfd contours based on actual terrain data, the propagation model in Recommendation ITU-R P.452-11, the FSS earth station's e.i.r.p. in 10 MHz bandwidth and the diameter and height above ground of its antenna

1 Generalities

This method produces a set of contours, using actual terrain data, showing the minimum separation distance from the low-water mark or neighbouring country's land border, an FSS earth station would need to meet in order to respect the pfd limits in RR No. 5.502, as a function of the earth station e.i.r.p. and the diameter and height of its antenna. An FSS earth station deployed within the contour based on its on-axis e.i.r.p. is assumed to meet the pfd limit criteria. No further analyses are required. This method, using more accurate data than Method 1, permits to obtain larger areas inside which an earth station can be deployed while meeting pfd limits of RR No.

5.502. However, it should be noted that deployment in areas excluded by this method is still possible provided a potential site can be shown to meet the pfd limit criteria through application of Method 3 (Annex 3). To account for different path loss due to different antenna heights, contours are to be defined for a range of earth station heights above local terrain level.

2 Step-by-step description of Method 2

Step 1: Definition of contours: Assuming several typical combinations of antenna diameter and associated on-axis e.i.r.p., a set of contours can be defined as figuring the areas where the considered earth station can be deployed while respecting the limits of RR No. 5.502. Taking into account the earth station discrimination between its direction of pointing and the direction of the border, a value of necessary path loss can be associated with each defined contour.

Step 2: Computation of contours: Knowing the value of the path loss to be associated with each contour, and taking into account an actual terrain database, it is possible to compute the position of each contour on a map. The propagation model to be used is the one described in Recommendation ITU-R P.452-11.

Step 3: Compliance with the pfd limits criteria in RR No. 5.502: This compliance is assessed by the comparison of the position of the earth station intended to be deployed with the contour associated with the corresponding profile:

- if the position of the earth station intended to be deployed is inside the associated contour, the earth station can be deployed with no additional measures while respecting the criteria of RR No. 5.502;
- if the position of the earth station intended to be deployed is outside the associated contour, additional considerations on the actual site environment are required.

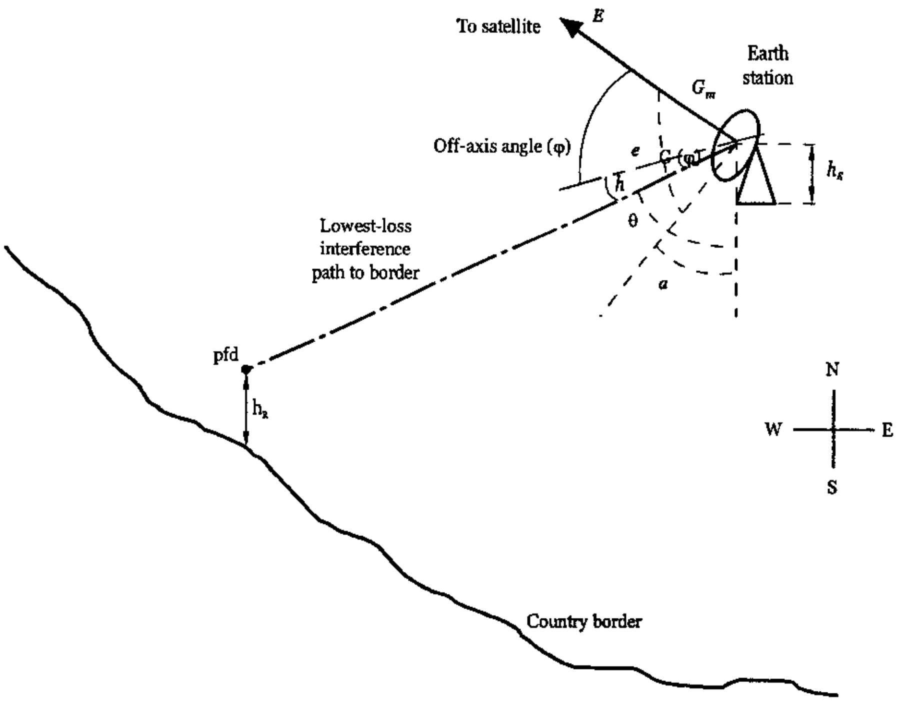
3 Possible application of Method 2

3.1 Interference scenario

The scenario for interference at the border of a country produced by an earth station within the country is illustrated in Figs. 5 and 6.

FIGURE 5

Geometry of interference path



E: earth station e.i.r.p. toward satellite (dB(W/10 MHz))

G_m: on-axis gain of earth station antenna (dBi)

$G(\varphi)$: earth station antenna gain in direction of horizon along the lowest-loss path to border (dBi)

a: azimuth angle of earth station antenna axis (degrees West of South)

e: elevation angle of earth station antenna axis (degrees)

h: elevation angle of the horizon in the direction of the lowest-loss path (degrees)

h_E: height above local ground level of earth station antenna focal point (m)

h_R: height above local ground level of radar antenna focal point (m)

pfd: power flux-density of interference at border (dB(W/(m² · 10 MHz)))

θ: azimuth angle of lowest-loss path to the border (degrees West of South)

It should be noted that the off-axis angle, φ, of interest here is the angle between the main beam axis and the axis representing the first part of the lowest-loss interference path, which in general will include a small elevation angle, *h* (usually between about –1° and +3°) (see Fig. 6).